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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/697,534	10/30/2003	Steve J. Shattil	CIPHY01	7591

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EXAMINER	
KIM, KEVIN	
ART UNIT	PAPER NUMBER
2611	

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Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

S1

Office Action Summary	Application No.	Applicant(s)
	10/697,534	SHATTIL, STEVE J.
	Examiner	Art Unit
	Kevin Y. Kim	2611

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *30 October 2003*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *3-20* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *3-20* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *30 October 2003* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

DETAILED ACTION

Claim Rejections - 35 USC § 102

1. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

2. Claims 3-6,8 are rejected under 35 U.S.C. 102(b) as being anticipated by Wiegandt et al.

Claims 3,8

Wiegandt et al discloses in a carrier Interferometry (CI) transmitter:

a CI coder adapted to encode at least one data sequence (K^{th} bit) onto a CI code ($i\Delta\theta_k$) to produce at least one data-bearing code vector, and

a (OFDM) modulator adapted to modulate the at least one data-bearing code vector onto a plurality of subcarriers.

See Fig 2 (a) and (b), and page 661, first paragraph.

Claims 4,5.

OFDM modulators includes an IFFT which reads on "an invertible transform module."

Claim 6.

Wiegandt et al discloses that the CI coder is adapted to scramble CI codes generated by the CI coder. See page 661, second paragraph.

Claim Rejections - 35 USC § 103

3. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

4. Claims 7,9-17 are rejected under 35 U.S.C. 103(a) as being unpatentable over Wiegandt et al in view of Steer et al (US 2003/0103445).

Claims 7 and 9.

Wiegandt discloses all the subject matter claimed except that at least one of the modulator and the CI coder is adapted to dynamically allocate subcarriers for at least one communication link.

Steer et al teaches dynamically allocating the subcarriers of OFDM to better accommodate the traffic requirements. See paragraph [0047].

Thus, it would have been obvious to one skilled in the art at the time the invention was made to adapt the OFDM modulator to dynamically allocate subcarriers for at least one communication link for the purpose of better accommodating the traffic requirements, as taught by Steer et al.

Claim 10.

Wiegandt et al is silent on whether the CI coding is non-uniform across the plurality of subcarriers. However, the CI coding is performed to ensure separability between bit k

and (N-1) other bits, non-uniform coding would have been obvious to increase separability between transmitted bits.

Claims 11,12,13,14,16

Although Wiegandt et al does not describe a CI receiver, an OFDM demodulator and a CI decoder corresponding to the OFDM modulator and CI coder would have been obvious by reversing the modulation and coding processes, as is commonly done in a communication system.

Claims 15 and 17.

An automatic frequency control (AFC) and interference cancellation are well known in the art to compensate carrier frequency variations and remove interference during transmission.

Claim Rejections - 35 USC § 101

5. 35 U.S.C. 101 reads as follows:

> Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title.

6. Claims 18-20 are rejected under 35 U.S.C. 101 because the claimed invention is directed to non-statutory subject matter.

The claimed invention is drawn to a signal constructed in a particular manner. A signal does not fall into any category of statutory subject matter.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Kevin Y. Kim whose telephone number is 571-272-3039. The examiner can normally be reached on 8AM --5PM M-F.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Jay Patel can be reached on 571-272-2988. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

June 20, 2007

AU 2611

KEVIN KIM
PRIMARY PATENT EXAMINER

/Kevin Kim/

Notice of References Cited	Application/Control No. 10/697,534	Applicant(s)/Patent Under Reexamination SHATTIL, STEVE J.	
	Examiner Kevin Y. Kim	Art Unit 2611	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
	A	US-			
	B	US-			
	C	US-			
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	Wiegandt et al, "Overcoming peak-to-peak average power ratio issues in OFDM via carrier-interferometry codes," 2001, IEEE, vol.2, pages 453-456
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

PEAK-TO-AVERAGE POWER REDUCTION IN HIGH-PERFORMANCE, HIGH-THROUGHPUT OFDM VIA PSEUDO-ORTHOGONAL CARRIER-INTERFEROMETRY CODING

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ABSTRACT OFDM (Orthogonal Frequency Division Multiplexing) is susceptible to high peak-to-average power due to an unstable envelope. Many solutions have been utilized in order to decrease the high peaks that are possible, but in these cases complexity is also added to the system architecture. This paper shows how Carrier Interferometry phase coding greatly reduces peaks in the signal envelope and in effect the problems associated with large PAPR.

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) has emerged as the standard in a number of high data rate technologies. Such standards include digital television broadcasting (such as European DAB and DVB-T [1]), and wireless local area networks (e.g., IEEE 802.11a operating at 5 GHz [2] and ETSI BRAN's HYPERLAN 2 standards [3]). By serial-to-parallel converting N bits and transmitting them simultaneously over N orthogonal carriers, OFDM achieves high data rates while avoiding multipath in frequency selective channels.

However, OFDM and its method of orthogonal carrier transmission are not without drawback. High peaks in power (up to N times the average) result from unstable envelopes, a consequence of using independently modulated carriers. This, in turn, leads to inefficient operation of the transmit power amplifier. A number of solutions to OFDM's peak-to-average power ratio (PAPR) problem have been proposed in the literature (i.e., block coding [4], partial transmit sequences [5], selective mapping [6], and clipping [7]), but while reducing the PAPR, they typically increase the complexity of the system.

In this paper, we demonstrate that Pseudo-Orthogonal Carrier-Interferometry OFDM (PO-CI/OFDM), first proposed in [8], eliminates the large power peaks and, hence, most PAPR issues, without significant rise in system complexity. PO-CI/OFDM proposed in [8] doubles the throughput of OFDM systems while better exploiting the frequency diversity of the fading channel. (The frequency diversity exploitation enables PO-CI/OFDM to increase throughput without loss in performance.) This is accomplished by transmission of *each* bit (of the $K = 2N$ bits) upon *each* of the N carriers through the novel use of Pseudo-Orthogonal Carrier-Interferometry (PO-CI) phase codes. Here, we show further advantage of this system: while the average power of PO-CI/OFDM is the same as that in OFDM, the peak values are much lower. Specifically, the phase codes applied to the N carriers result in one bit's power reaching a maximum, when the powers of the remaining $2N-1$ bits are at a minimum. Therefore, we show a more stable envelope, and, ultimately, an average PAPR and standard deviation of PAPR far smaller than that of OFDM.

We also compare PO-CI/OFDM to an OFDM system where clipping has been employed. Since the complexity increase in PO-CI/OFDM is minimal when compared with that of the PAPR reduction methods listed earlier, clipping was chosen because its methodologies are less complex in nature. As with "straight OFDM," we show PO-CI/OFDM has better PAPR characteristics than the clipped OFDM architecture.

Section II reviews the system architectures; Section III discusses the PAPR comparison between PO-CI/OFDM and OFDM; Section IV depicts the simulation and results; and analysis and conclusions follow.

II. SYSTEM ARCHITECTURES

A. OFDM and PO-CI/OFDM

Both OFDM and PO-CI/OFDM serial-to-parallel convert the input bits. Next, in OFDM, each bit is modulated onto its own carrier and sent out over the channel. OFDM's transmitted signal is characterized mathematically as:

$$s(t)_{OFDM} = \sum_{k=0}^{N-1} a_k \cos(2\pi f_c t + 2\pi f_k t) \tag{1}$$

where: (1) a_k is the k^{th} bit and is assumed to be +1 or −1 with equal probability; and (2) $f_k = k\Delta f$, and $\Delta f = 1/T_b$ (T_b is the bit rate after serial-to-parallel conversion) to assure orthogonality among carriers.

In PO-CI/OFDM, as discussed in [8], after serial-to-parallel conversion, *each* bit is modulated onto *all* of the N carriers, and separability of the bits is maintained through use of carefully selected phase offsets. The transmitted signal for the k^{th} bit in PO-CI/OFDM is therefore:

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$$s_k(t)_{PO\text{-}CI/OFDM} = \frac{1}{\sqrt{N}}\sum_{i=0}^{N-1} a_k \cos(2\pi f_c t + 2\pi f_i t + i\Delta\theta_k) \tag{2}$$

where: (1) a_k is the k^{th} bit and is assumed to be +1 or −1 with equal probability; (2) $f_i = i\Delta f$, and $\Delta f = 1/T_b$ (T_b is the bit rate after serial-to-parallel conversion) to assure orthogonality among carriers; (3) $i\Delta\theta_k$ is added as the phase offset used to ensure separability between bit k and the (K-1) other bits; and (4) $1/\sqrt{N}$ ensures a bit energy of unity.

The PO-CI/OFDM transmitted signal, over an entire OFDM block of K bits is thus:

$$s(t)_{PO\text{-}CI/OFDM} = \frac{1}{\sqrt{N}}\sum_{k=0}^{K-1}\sum_{i=0}^{N-1} a_k \cos(2\pi f_c t + 2\pi f_i t + i\Delta\theta_k) \tag{3}$$

The addition of the $i\Delta\theta_k$ phase offset (to the i^{th} carrier of bit k) allows the receiver to separate the K bits co-located on identical carriers. Specifically, phase offsets are utilized allowing support of $K = 2N$ bits on N carriers. This is accomplished by (1) defining the first set of phase offsets for bits $k = 0, 1, \ldots, N-1$ according to

$$\Delta\theta_k = \frac{2\pi}{N}k,\ k = 0,1,\ldots,N-1 \tag{4}$$

and (2) assigning the next set of N bits ($k = N, N+1, \ldots, 2N-1$) phase offsets defined by

$$\Delta\theta_k = \frac{2\pi}{N}(k-N)+\frac{\pi}{N}. \tag{5}$$

The first set of bits ($k = 0, 1, \ldots, N-1$) can be shown to be orthogonal to one another, and the second set of bits ($k = N, N+1, \ldots, 2N-1$) are also orthogonal to one another, but pseudo-orthogonal to the first set. Specifically, the second set of phase offsets are chosen to minimize inter-bit interference with the first set.

B. OFDM WITH CLIPPING

Direct clipping of OFDM signals creates (1) spectral spreading (requiring additional filtering) and (2) in-band distortion (in order to reduce the power peaks). To circumvent these concerns, we instead utilize Gaussian pulses to attenuate the OFDM signal at positions when the amplitude breaches the desired maximum amplitude, A_o [9][10]. This Gaussian technique offers filtering qualities which reduce any spectral spreading. As shown in [10], the corrected signal $c(t)$ is created via:

$$c(t) = s(t)k(t) \tag{6}$$

where s(t) is the original signal, and k(t) is defined as:

$$k(t) = 1 - \sum_{n=-\infty}^{\infty} A_n g(t-t_n) \tag{7}$$

$$g(t) = e^{-t^2/2\sigma^2} \tag{8}$$

and

$$A_n = \frac{|s(t_n)| - A_o}{|s(t_n)|} \tag{9}$$

In an OFDM system with bandwidth BW, σ is chosen as σ = 5/BW.

III. PAPR COMPARISON

PAPR is defined as the peak power per OFDM symbol versus the average power in that same symbol, or mathematically:

$$PAPR = \frac{\max_{0<t<T_s}|s(t)|^2}{mean_{0<t<T_s}|s(t)|^2} \tag{10}$$

The average power of PO-CI/OFDM and OFDM is:

$$P_{mean} = NP_o \tag{11}$$

where Po is the power of one carrier, i.e.,

$$\left(P_o = \frac{1}{2}A_o^2\right) \tag{12}$$

The OFDM method of serial-to-parallel converting incoming information bits and transmitting each bit on its own unique carrier leads to the potential for high peak power (i.e., N times the average). This is a result of possible in-phase, coherent addition of the carriers, and as the number of carriers (N) increases, so does the peak power's maximum level. In its worst case (WC), where the N carriers coherently add, OFDM's peak power is equal to:

$$P^{WC}_{(\max)_{OFDM}(0<t<T_s)} = \left(\sum_{i=1}^{N} A\right)^2 = (NA)^2 = \frac{1}{2}N^2A^2 \tag{13}$$

where A is the amplitude of any given carrier, and N is the number of carriers.

In PO-CI/OFDM, as discussed in section II, *all* bits are transmitted simultaneously over *all* carriers, and an appropriate selection of phase offsets makes bits separable at the receiver. However, these phase offsets have a second benefit: they reduce the peak power. Specifically, they ensure that when one bit's carriers add coherently, other bit's carriers do not add

coherently. Mathematically, the maximum or peak power from equation (3) is much less than the summation of maximum carrier powers in (2), because when $S_k(t)$ reaches its maximum (i.e., P_o), $S_j(t)$ (where $(j \neq k)$), is at a minimum (i.e., $P_j <<$ P_o) or a very low value. Therefore, $P_{\max(PO-CI/OFDM)}$ is much less than $P_{\max(OFDM)}$. That is, considering worst case scenarios:

$$PAPR_{WC(OFDM)} = \frac{N^2 P_o}{NP_o} = N \tag{14}$$

and

$$PAPR_{WC(PO-CI/OFDM)} = \frac{\left(\frac{1}{2}\max_{0<t<T_s}|s(t)|\right)^2}{NP_o} << N \tag{15}$$

IV. SIMULATION

Figure 1 illustrates PAPR levels across 10,000 transmissions for 32-bit, 32-carrier OFDM (black) and 64-bit, 32-carrier PO-CI/OFDM (gray).

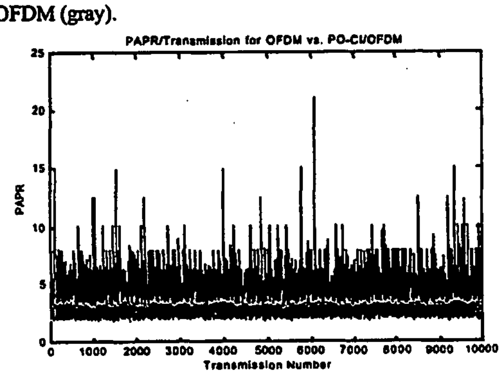

Figure 1: PAPR/Transmission OFDM vs. PO-CI/OFDM

Referring to Figure 1, OFDM's PAPR can be characterized as erratic, displaying a mean PAPR of 3.8, and consistently reaching levels exceeding 6 (5% of the time), with some PAPR values exceeding 15 and even 20. PO-CI/OFDM, on the other hand, displays no PAPR value above 4.4 and stays close to its mean PAPR level of 2.5.

Figure 2 demonstrates the standard deviation of the PAPR as a function of increasing number of carriers. As the number of carriers increases, the standard deviation of OFDM's PAPR also increases, but the opposite is true in PO-CI/OFDM: in PO-CI/OFDM, the standard deviation of the PAPR decreases with increasing number of carriers. For the 32-bit, 32-carrier OFDM and 64-bit, 32-carrier PO-CI/OFDM systems shown in Figure 1, OFDM's PAPR demonstrates a standard deviation of 1.23 (a variance of 1.5), while PO-CI/OFDM's standard deviation is only 0.355 (a variance of 0.125).

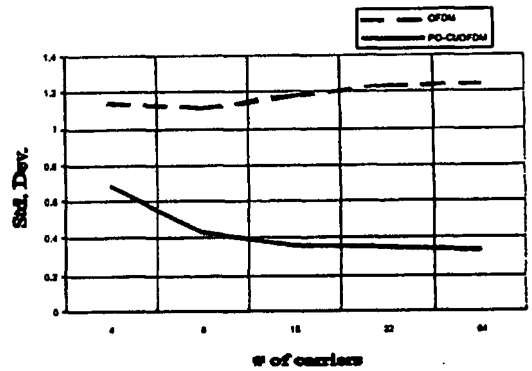

Figure 2: PAPR standard deviation for OFDM vs. PO-CI/OFDM

When compared to an OFDM system that has had the clipping algorithm of section II B applied, similar results are observed. Figure 3 displays the PAPR levels across 10,000 transmissions for a 32-bit, 32-carrier OFDM system with clipping (in black), and the 64-bit, 32-carrier PO-CI/OFDM system (in gray). Here, a Clipping Ratio (CR), as defined in [7], of 1.4 was implemented ($A_o = 7.9196$).

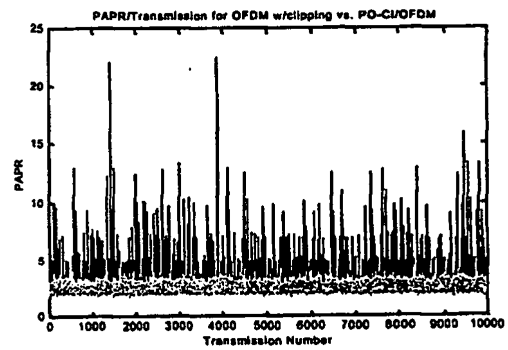

Figure 3: PAPR/Transmission OFDM w/clippping vs. PO-CI/OFDM

Referring to Figure 3, the clipping algorithm has greatly reduced the number of times the PAPR exceeds a level of 5, but spurious levels are still prevalent. The mean and standard deviation of PAPR with clipping are reduced to 2.412 and 1.053 respectively.

Figure 4, which plots the pdf (probability density function) of the PAPR, shows that clipping effectively concentrates the PAPR levels about the mean, but does little to contain the spurious peaks. This can be directly attributed to the in-band distortion caused by clipping.

Referring to Figure 5, the cumulative distribution function (CDF) of the PAPR is depicted. As seen, clipping and filtering improve the statistics of OFDM, (mean 2.412 and standard deviation 1.053), but it is not until $y = 22.5$ that Pr(PAPR $< y$) = 100%, which is a result equivalent to that of unclipped OFDM. PO-CI/OFDM, on the other hand, demonstrates Pr(PAPR $< y$) = 100% when $y = 4.4$.

transmitter and receiver complexity in PO-CI/OFDM, relative to current OFDM, is minimal when compared to the substantial throughput gains and PAPR reduction.